US 20110015520A1

(19) **United States**

(12) **Patent Application Publication**

Meetz et al.

(10) **Pub. No.: US 2011/0015520 A1**

(43) **Pub. Date: Jan. 20, 2011**

(54) **PERFUSION IMAGING**

(75) Inventors: **Kirsten Meetz**, Hamburg (DE); **Ingwer Carlsen**, Hamburg (DE); **Heinrich Schulz**, Hamburg (DE); **Rafael Wiemker**, Kisdorf (DE); **Stewart Young**, Hamburg (DE)

Correspondence Address:
PHILIPS INTELLECTUAL PROPERTY & STANDARDS
P.O. BOX 3001
BRIARCLIFF MANOR, NY 10510 (US)

(73) Assignee: **KONINKLIJKE PHILIPS ELECTRONICS N.V.**, EINDHOVEN (NL)

(21) Appl. No.: **12/920,483**

(22) PCT Filed: **Feb. 25, 2009**

(86) PCT No.: **PCT/IB09/50757**

§ 371 (c)(1),
(2), (4) Date: **Sep. 1, 2010**

Related U.S. Application Data

(60) Provisional application No. 61/037,010, filed on Mar. 17, 2008.

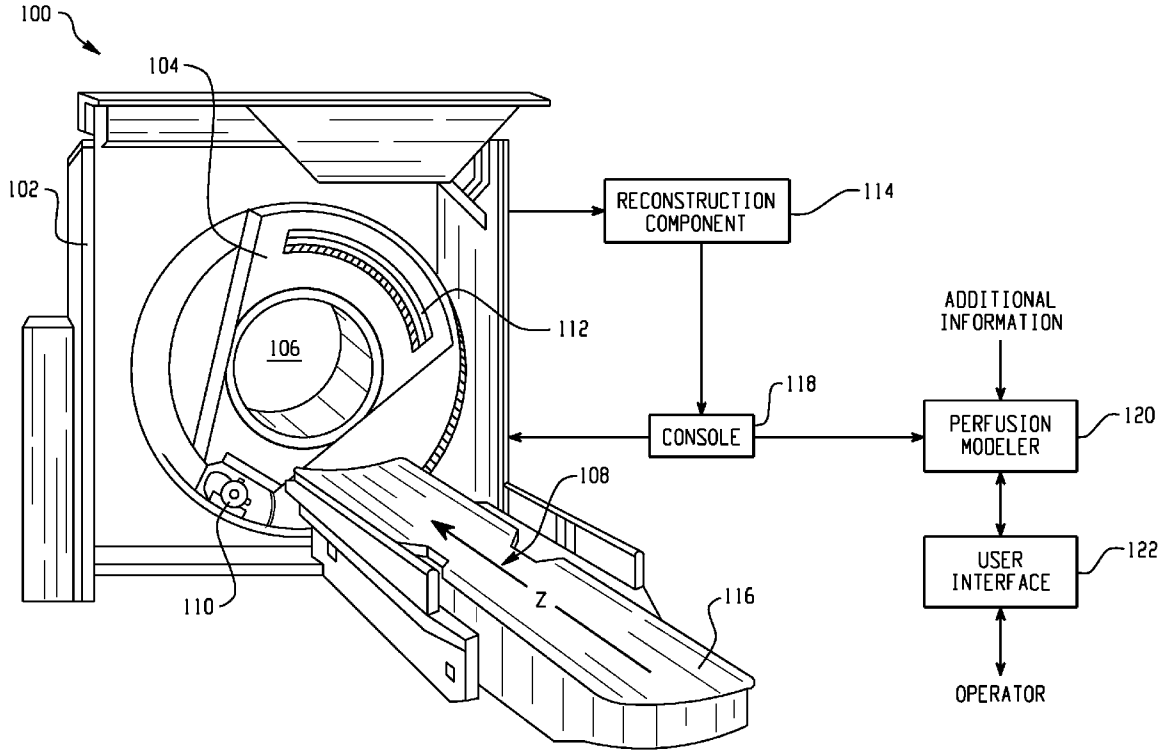
Publication Classification

(51) **Int. Cl.**
A61B 6/00 (2006.01)
G06K 9/00 (2006.01)

(52) **U.S. Cl.** **600/425**; 382/128; 382/131

(57) **ABSTRACT**

A perfusion analysis system includes a perfusion modeller (**120**) and a user interface (**122**). The perfusion modeller (**120**) generates a patient specific perfusion model based on medical imaging perfusion data for the patient, a general perfusion model, and a quantification of one or more identified pathologies of the patient that affect perfusion in the patient. The user interface (**122**) accepts an input indicative of a modification to the quantification of the one or more identified pathologies. In response, the perfusion modeller (**120**) updates the patient specific perfusion model based on the medical imaging perfusion data for the patient, the general perfusion model, and the quantification of the one or more identified pathologies of the patient, including the modification thereto.



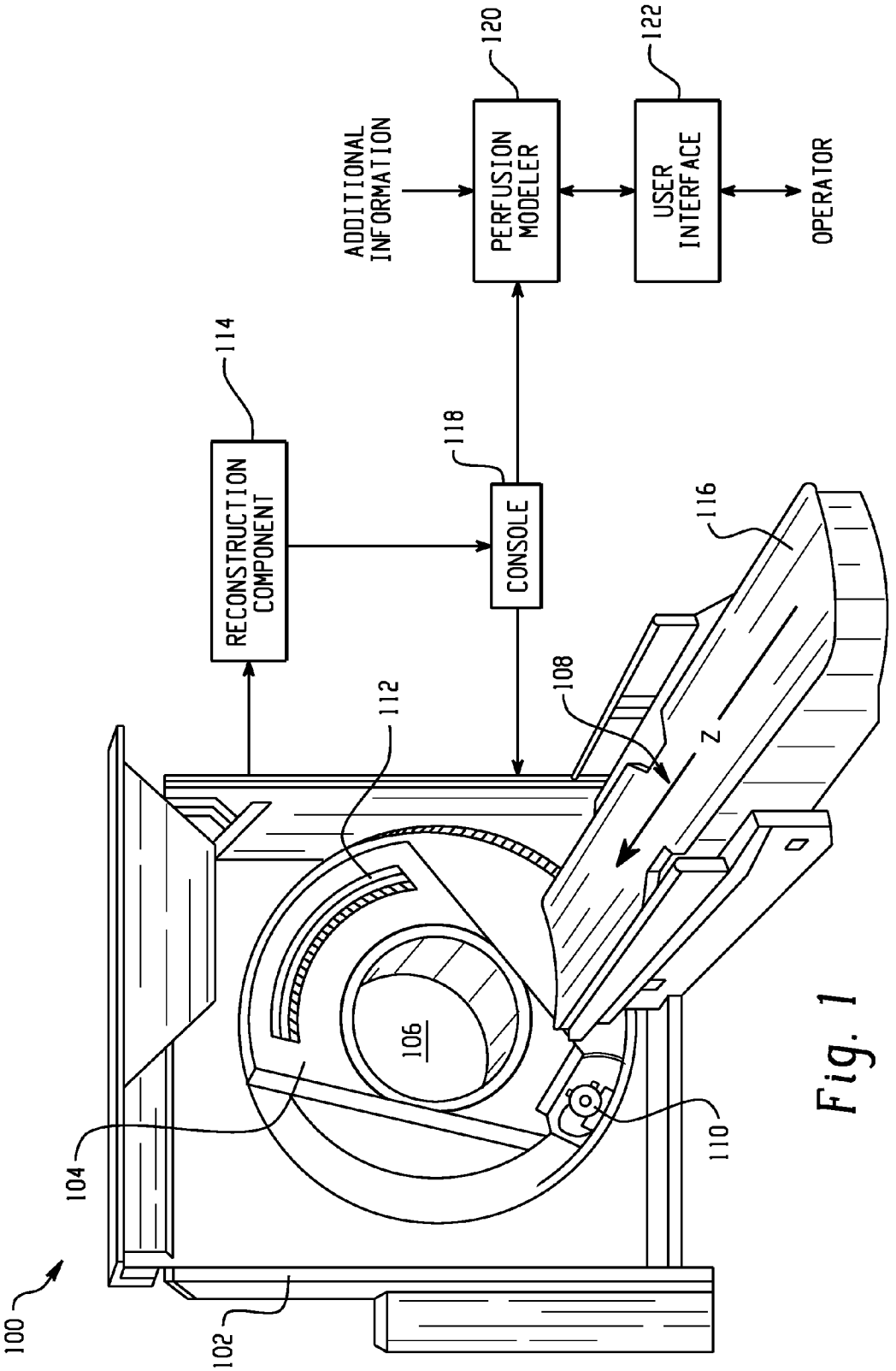

100
102
104
106
108
110
112
114
116
118
120
122
RECONSTRUCTION COMPONENT
CONSOLE
PERFUSION MODELER
USER INTERFACE
ADDITIONAL INFORMATION
OPERATOR
Z

Fig. 1

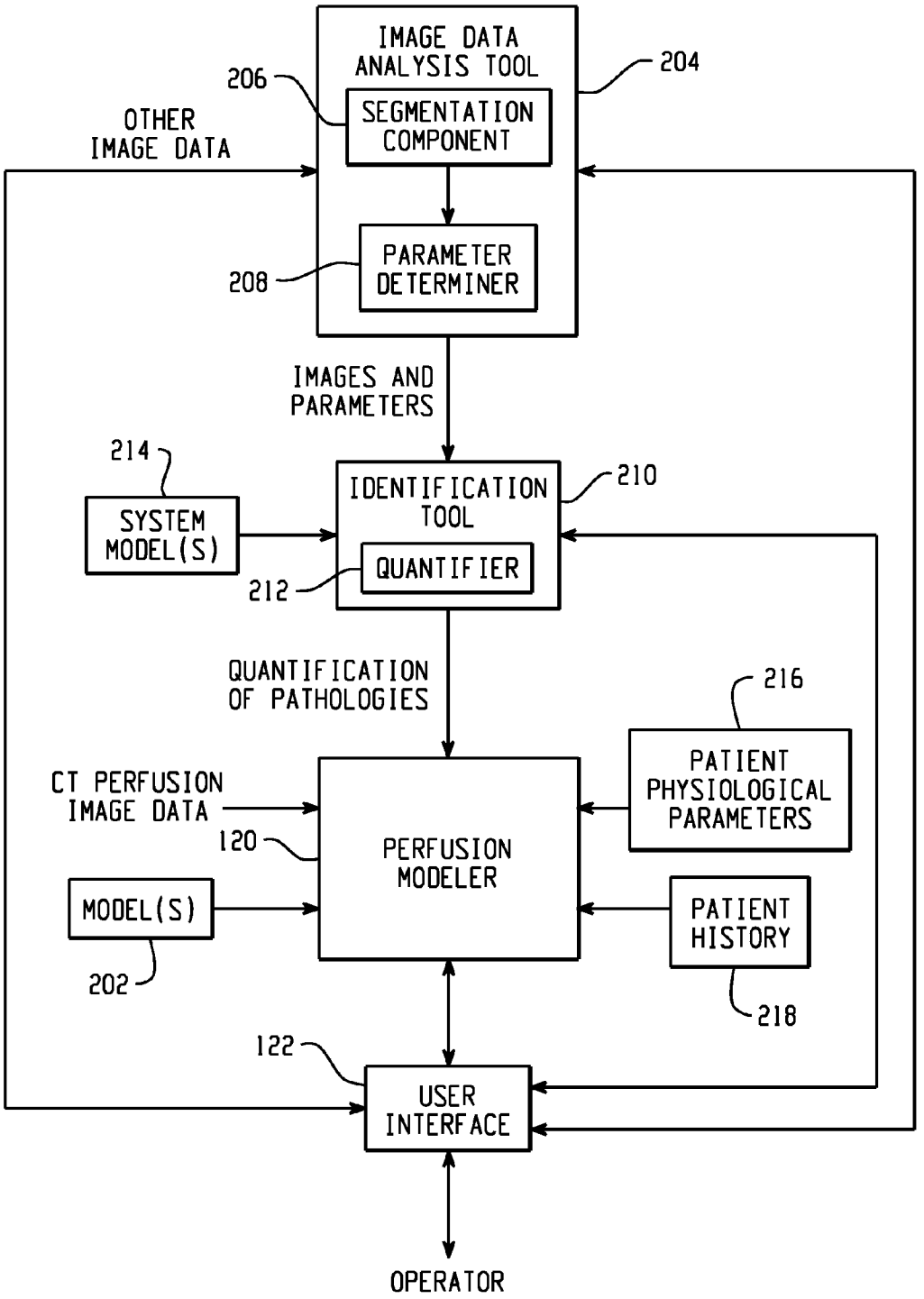


IMAGE DATA ANALYSIS TOOL
204
206
SEGMENTATION COMPONENT
OTHER IMAGE DATA
208
PARAMETER DETERMINER
IMAGES AND PARAMETERS
214
SYSTEM MODEL(S)
IDENTIFICATION TOOL
210
212
QUANTIFIER
QUANTIFICATION OF PATHOLOGIES
216
PATIENT PHYSIOLOGICAL PARAMETERS
CT PERFUSION IMAGE DATA
120
PERFUSION MODELER
MODEL(S)
PATIENT HISTORY
202
218
122
USER INTERFACE
OPERATOR

Fig. 2

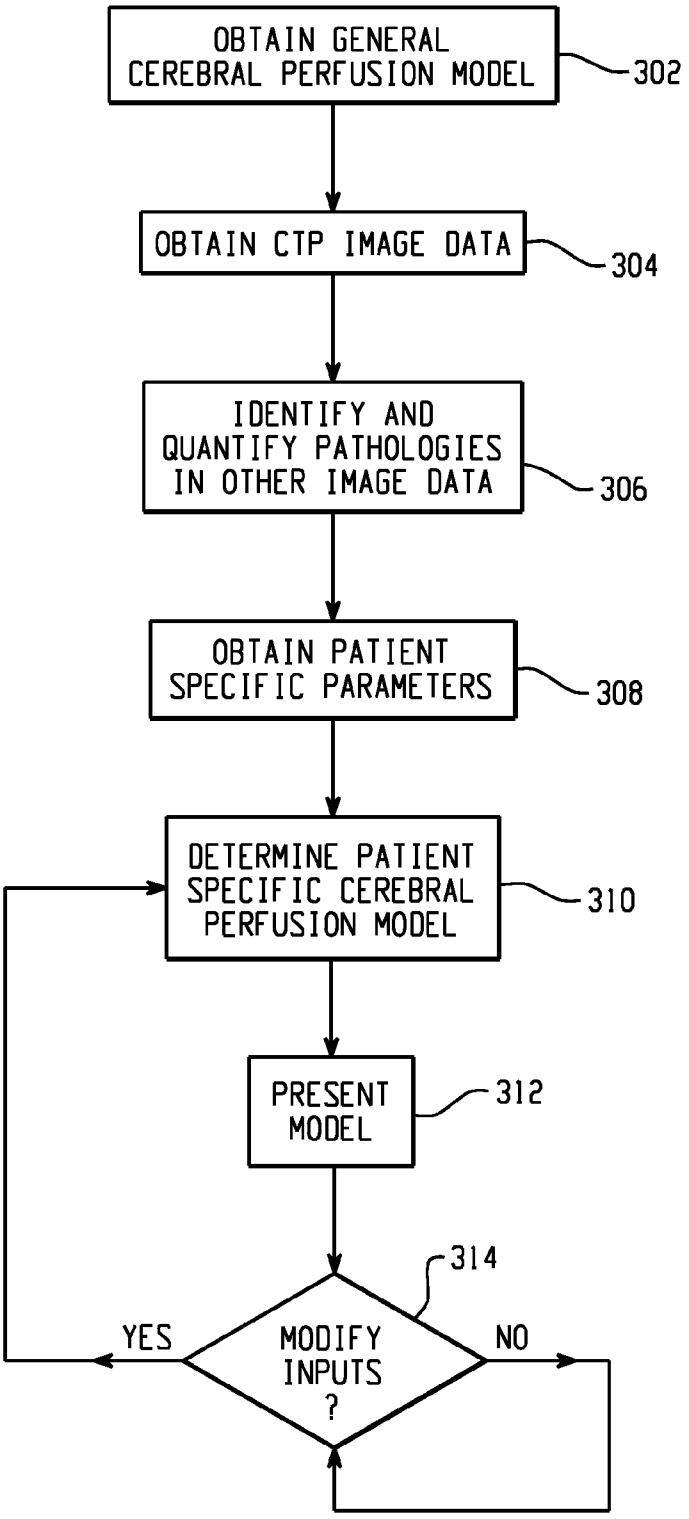

OBTAIN GENERAL CEREBRAL PERFUSION MODEL
302
OBTAIN CTP IMAGE DATA
304
IDENTIFY AND QUANTIFY PATHOLOGIES IN OTHER IMAGE DATA
306
OBTAIN PATIENT SPECIFIC PARAMETERS
308
DETERMINE PATIENT SPECIFIC CEREBRAL PERFUSION MODEL
310
PRESENT MODEL
312
314
MODIFY INPUTS ?
YES
NO

Fig. 3

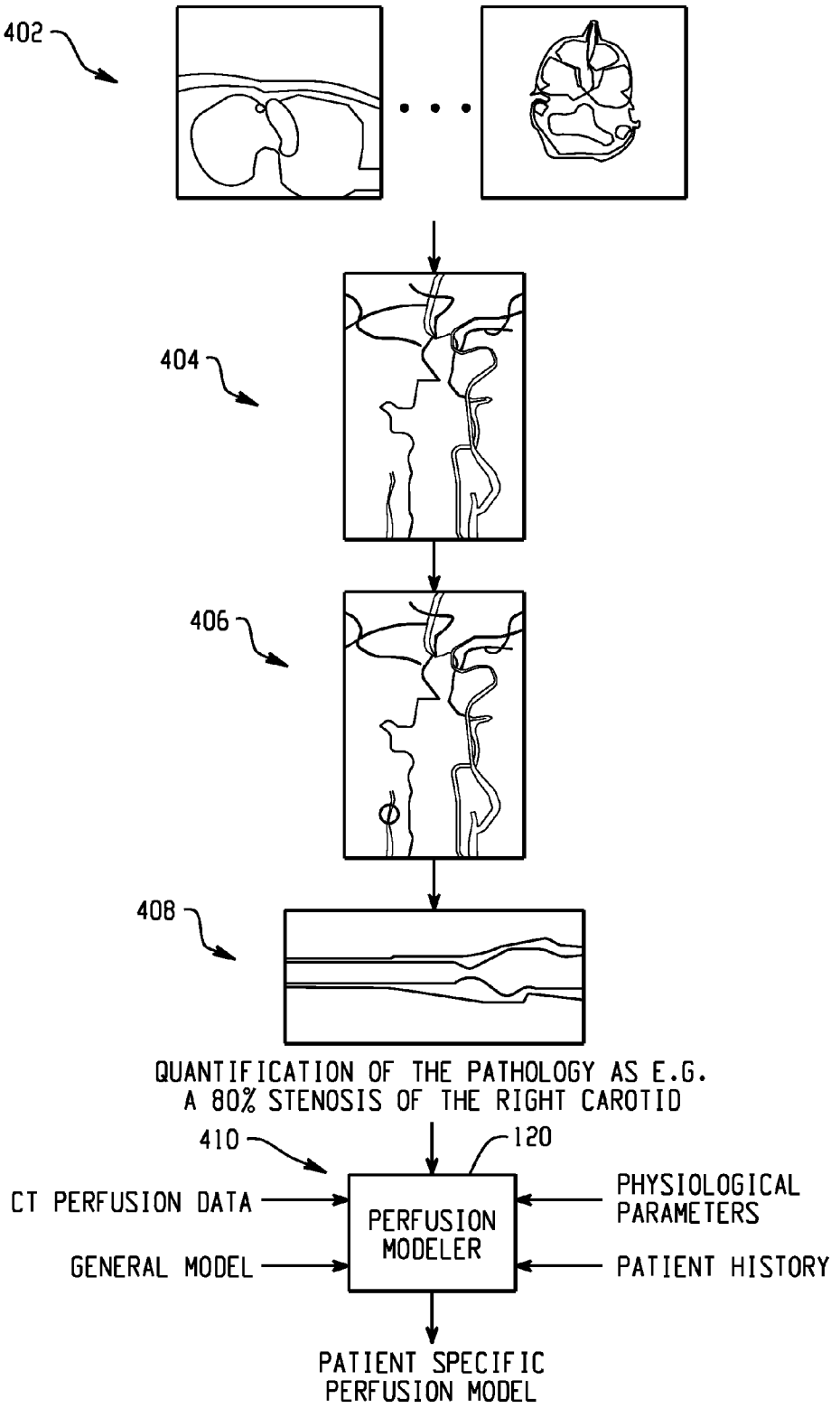

402
404
406
408
QUANTIFICATION OF THE PATHOLOGY AS E.G.
A 80% STENOSIS OF THE RIGHT CAROTID
410
120
CT PERFUSION DATA
GENERAL MODEL
PERFUSION MODELER
PHYSIOLOGICAL PARAMETERS
PATIENT HISTORY
PATIENT SPECIFIC PERFUSION MODEL

Fig. 4

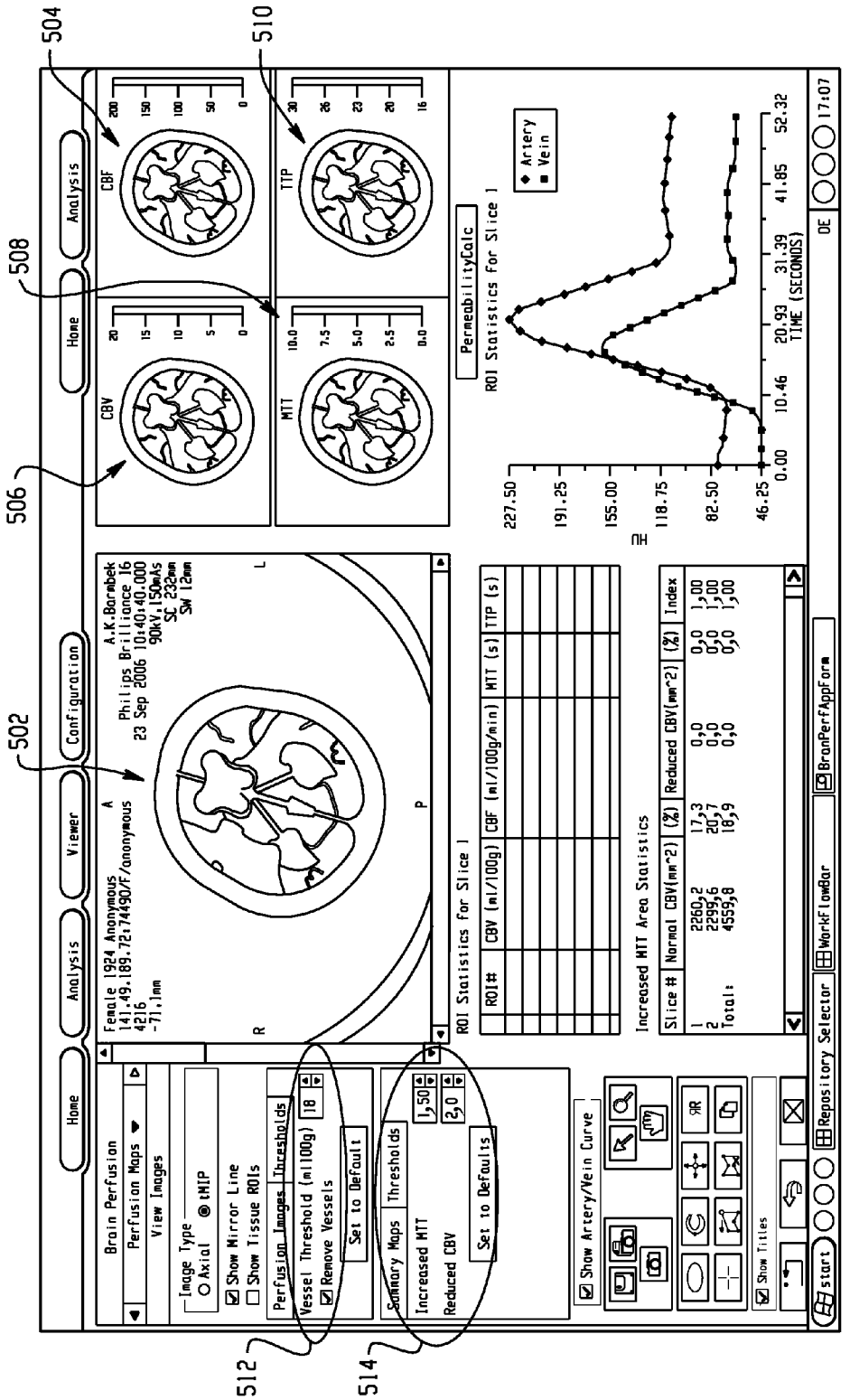


Fig. 5 (PRIOR ART)

PERFUSION IMAGING

[0001] The following generally relates to perfusion imaging, and finds particular application to computed tomography perfusion (CTP). However, it also amenable to other medical imaging applications and to non-medical imaging applications.

[0002] Computed tomography perfusion (CTP) is a medical imaging technique that is used to facilitate diagnosing patients with mal-perfusion of the brain like stroke patients. In general, the procedure begins with administering an intravenous contrast agent bolus to a patient. Then, the patient's brain is scanned. The contrast agent causes the x-ray density of the brain to temporarily increase as the contrast agent flows through the vascular structure of the brain. The imaging technique includes acquiring data that covers multiple different time intervals so that the contrast agent is captured and traced as the contrast agent flows through the vascular structure of the brain. The resulting image data can be used identify ischemic tissue and/or differentiate between irreversibly damaged tissue (necrotic tissue, or the core of the infarct) and potentially reversibly damaged tissue (at-risk tissue, or the penumbra of the infarct), for example, in stroke patients.

[0003] Software application brain perfusion packages provide tools that facilitate automatically or semi-automatically interpreting CTP image data. Such packages may not only calculate perfusion maps showing cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), and time to peak (TTP), but, in addition, may facilitate interpreting these perfusion maps by generating summary maps in which areas of hypo-perfusion are differentiated in the core of an infarct and the penumbra of the infarct. This differentiation may impact the therapeutic decision making, for example, where the quotient of the area of the core and the penumbra is used to decide whether thrombolytic therapy should be applied in an attempt to save potentially reversibly damaged tissue. For illustrative purposes, FIG. **5** shows a graphical user interface of an example software application brain perfusion package. In this example, a summary map **502**, a CBF perfusion map **504**, a CBV perfusion map **506**, a MTT perfusion map **508**, and a TTP perfusion map **510** are presented in the graphical user interface.

[0004] However, cerebral perfusion and diffusion deficits cannot be interpreted as a disease of the brain alone; they typically are treated and interpreted as a systemic disease, which may be caused by different malfunctions or malformations of the vascular system. Unfortunately, some contemporary software application brain perfusion packages may rely on brain perfusion image data alone. This can lead to a misinterpretation, for example, in cases where the perfusion deficit is apparent in the image data of the brain, but located outside the brain. For example, a stenosis of a carotid may mimic a mal-perfusion such as a hypo-perfusion of the corresponding cerebral hemisphere. Thus, additional information about the status of the extra-cranial vascular system should be used to allow for a more reliable interpretation of a CTP study of the brain.

[0005] Conventionally, a clinician such as a radiologist or the like interprets the perfusion map and/or the summary maps derived from the CTP image data and interprets the additional information, and mentally pieces the interpretations together and/or manually tweaks the parameters of the perfusion and/or summary maps based on the interpretation of the additional information. The later is shown in FIG. **5** in which the user manually adjusts a perfusion map parameter **512** and/or summary map parameters **514** via the graphical user interface. Unfortunately, determining such parameters can be tedious, time-consuming and prone to error. By way of example, where the additional information includes angiographic studies such as CT angiographies (CTA) that cover the body from the head to the heart, the clinician interprets the angiographic studies and then combines the image based findings (CTP and CTA) with clinical symptoms, for example, by determining suitable perfusion parameters based on the CTA findings and then adjusting the parameters **512** and **514** in the graphical user interface accordingly.

[0006] Furthermore, if new additional information becomes available or if any of the additional information changes, the clinician has to interpret the new or changed information and again mentally combine the findings and set the parameters **512** and **514** accordingly. As a consequence, although the additional information allows for a more reliable interpretation of a CTP study, it requires further interpretation of additional information outside of the CTP image data to generate parameters used to compensate or adjust for the shortcomings of the CTP analysis.

[0007] Aspects of the present application address the above-referenced matters and others.

[0008] According to one aspect, a perfusion analysis system includes a perfusion modeller and a user interface. The perfusion modeller generates a patient specific perfusion model based on medical imaging perfusion data for the patient, a general perfusion model, and a quantification of one or more identified pathologies of the patient that affect perfusion in the patient. The user interface accepts an input indicative of a modification to the quantification of the one or more identified pathologies. In response, the perfusion modeller updates the patient specific perfusion model based on the medical imaging perfusion data for the patient, the general perfusion model, and the quantification of the one or more identified pathologies of the patient, including the modification thereto.

[0009] According to another aspect, a brain perfusion analysis method includes identifying a first pathology of the vascular system, quantifying the first pathology, and generating a first patient specific brain perfusion model based on the quantification of the first pathology, a general brain perfusion model, and brain perfusion imaging data.

[0010] According to another aspect, a computer readable storage medium containing instructions which, when executed by a computer, cause the computer to perform the steps of: identifying a pathology of the vascular system; quantifying the pathology; and generating a patient specific brain perfusion model based on a quantification of the pathology, a general brain perfusion model, and a perfusion imaging data.

[0011] The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

[0012] FIG. **1** illustrates a medical imaging system, including a perfusion modeller.

[0013] FIG. **2** illustrates example inputs to the perfusion modeller.

[0014] FIG. **3** illustrates a flow diagram for modeling perfusion.

[0015] FIG. **4** illustrates a flow diagram for modeling perfusion.

[0016] FIG. **5** illustrates a prior art perfusion technique.

[0017] Initially referring to FIG. **1**, a computed tomography (CT) scanner **100** includes a stationary gantry **102**, which is stationary in the sense that it is generally stationary during scanning. However, the stationary gantry **102** may be configured to tilt and/or otherwise be moved.

[0018] The scanner **100** also includes a rotating gantry **104**, which is rotatably supported by the stationary gantry **102**. The rotating gantry **104** rotates around an examination region **106** about a longitudinal or z-axis **108**.

[0019] A radiation source **110**, such as an x-ray tube, is supported by and rotates with the rotating gantry **104** around the examination region **106**. A fourth generation system is also contemplated. The radiation source **110** emits generally fan, wedge, or cone shaped radiation that traverses the examination region **106**.

[0020] A radiation sensitive detector array **112** detects photons emitted by the radiation source **110** that traverse the examination region **106** and generates projection data indicative of the detected radiation. The illustrated radiation sensitive detector array **112** includes one or more rows of radiation sensitive photosensors that extend in a z-axis or longitudinal direction, and one or more columns of radiation sensitive photo sensors that extend in a traverse direction.

[0021] A reconstructor **114** reconstructs the projection data from the detectors to generate volumetric image data indicative of the examination region **106**, including the interior anatomy, such as a portion of the vascular system, of a patient disposed in the examination region **106**.

[0022] A patient support **116**, such as a couch, supports a patient in the examination region **106**. The patient support **116** is movable along the z-axis **108** in coordination with the rotation of the rotating gantry **104** to facilitate helical, axial, or other desired scanning trajectories.

[0023] A general purpose computing system **118** serves as an operator console, which includes human readable output devices such as a display and/or printer and input devices such as a keyboard and/or mouse. Software resident on the console **118** allows the operator to control the operation of the system **100**, for example, by allowing the operator to select or define a scan protocol, initiate and terminate scanning, view and/or manipulate the volumetric image data, and/or otherwise interact with the system **100**.

[0024] In one instance, the scanner **100** is used to perform a cerebral perfusion scan. Such a scan may include administering an intravenous contrast medium bolus, such as an iodinated contrast agent, to a subject, and then scanning the subject's brain over time. Following the administration of the contrast medium bolus, the x-ray density of the brain temporarily changes as the contrast medium flows through the vascular structure of the brain, and the quantity of the contrast material is captured and tracked as it passes through the vascular structure of the brain. As noted above, the resulting image data can be used identify ischemic tissue and/or differentiate between irreversibly damaged tissue and potentially reversibly damaged tissue, for example, in stroke patients or patients with another neuro-vascular disease. Of course, the scanner **100** can additionally or alternatively be used for other CT applications.

[0025] When performing such a cerebral perfusion scan, the resulting image data can be transferred to a perfusion modeller **120**. In this example, the perfusion modeller **120** is part of a workstation or the like, which is separate from the scanner **100**. However, the perfusion modeller **120** can additionally or alternatively be implemented in the console **118** and/or be part of another system. The perfusion modeller **120** generates patient specific cerebral perfusion information at least in part from the image data. In one instance, the patient specific cerebral perfusion information is an adaptation of a general cerebral perfusion model. The general model may include an equation or the like in terms of various perfusion related parameters, be based on one or more rules, etc. Such a general model may be modified to include and/or remove a parameter(s), change a dependency(s), and/or otherwise be modified.

[0026] In one instance, the patient specific perfusion model includes information indicative of parameters such as cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), time to peak (TTP), and/or one more other parameters, and/or summary information. As shown, the illustrated perfusion modeller **120** also uses other or additional information to generate the patient specific cerebral perfusion model. As described in greater detail below, the additional information may include image data from other scans and/or information derived therefrom, physiological parameters (e.g., vital signs), patient history, patient pathologies such as vascular pathologies, etc.

[0027] A user interface **122** provides a mechanism through with an operator and the perfusion modeller **120** interact with each other. Such interaction may include presenting, via the user interface **122**, various information such as individual and/or superimposed images from one or more imaging procedures. For example, the user interface **122** may present CT data, CTP data, CTA data, data from other imaging modalities, and/or a combination (via overlays or superposition) thereof as two- or three-dimensional image data and/or other image data and/or as time sequences of the before mentioned data. The user interface **122** may additionally or alternatively present pathologies within the images, the perfusion maps (e.g., CBF, CBV, MTT and/or TTP maps), summary maps, statistics, parameter settings, etc. Such interaction may also include operator input such as additions, modifications, and/or deletions to the information provided to and used by the perfusion modeller **120** to generate the patient specific cerebral perfusion model.

[0028] It is to be appreciated that the perfusion modeller **120** dynamically updates or generates the patient specific cerebral perfusion model as its inputs change, for example, as parameters are added, modified, and/or removed. For example, a clinician may discover a pathology (e.g., a stenosis) in a CTA image that was not previously identified as a pathology. The clinician, via the user interface **122**, may mark or otherwise identify the pathology to the perfusion modeller **120**. In response, the perfusion modeller **120** updates or generates a patient specific perfusion model based on a combination of the CTP image data and the additional information, which now also includes the newly identified pathology. In instances in which such additional information is not used by the perfusion modeller **120**, the clinician may be tasked with interpreting the additional information (e.g., other images, physiological parameters, etc.) and mentally drawing conclusions based on both the CTP findings (e.g., the perfusion maps showing CBF, CBV, MTT and ITT, and the summary map) and the findings from the additional information, and/or determining various parameters from the findings from the

additional information and using the findings to determine parameters used to compensate for shortcomings in the CTP findings.

[0029] FIG. **2** illustrates a non-limiting example showing various types of inputs that may be used by the perfusion modeller **120** to generate the patient specific cerebral perfusion model. As discussed above, one of the inputs is the CT perfusion image data acquired by the scanner **100**. Another input includes a general cerebral perfusion model **202**. Such a model may be based on parameters such as systemic parameters like blood pressure, cardiac parameters like heart rate, vascular parameters like the perimeter of the carotids, changes in cerebral perfusion parameters caused by pathological inputs, and/or other parameters. Examples of suitable cerebral perfusion parameters include, but are not limited to, parameters indicative of a cerebral mal-perfusion, delayed means transit time cause by low blood pressure, etc. It is to be appreciated that the parameters and/or dependencies of the model can be changed, including tailored for a particular patient, pathology, and/or clinician. In this example, the CT perfusion image data, the general cerebral perfusion model **202**, and one or more of the following additional information is used by the perfusion modeller **120** to generate a patient specific cerebral perfusion model.

[0030] In one instance, the additional information includes pathological information such as a quantification of pathologies and/or pathological information. In one example, the quantification of a pathology is determined from image data. Such image data may be CT data, including CT angiography (CTA) data, CTP data, and/or other CT data, from the scanner **100** or another CT scanner, and/or image data from different imaging modalities, including magnetic resonance (MR), ultrasound (US), single photon emission computed tomography (SPECT), positron emission tomography (PET), etc. The image data is processed by an image data analysis tool **204**.

[0031] A segmentation component **206** segments the image data, for example, to extract one or more regions of interest (ROI) and/or discard one or more regions outside of the one or more ROI's. This can be done automatically and/or with human intervention. In one example, the segmented data includes information indicative of vascular structures. For instance, the segmentation component **206** can segment CTA images or the like to obtain vascular structures such as a vascular tree. A parameter determiner **208** of the image data analysis tool **204** determines various vascular parameters from the segmented vascular structures. Examples of such parameters include parameters indicative of the perimeter of the carotids, cerebral mal-perfusion (e.g., hypo-perfusion caused by stenosis), delayed means transit time cause by low blood pressure, etc.

[0032] An identification tool **210** identifies and quantifies pathologies in the vascular structure based on the segmented data and the parameters derived therefrom by the image data analysis tool **204**. In one instance, a quantifier **212** of the identification tool **210** compares the image data of the segmented vascular structures with one or more models **214** including image data with vascular structure with known pathologies to identify pathologies. In another instance, a machine learning technique, such as through an implicitly and/or explicitly trained classifier, probabilities, cost functions, statistics, heuristics, or the like are used to identify vascular pathologies. The quantification of the identified pathologies are provide to the perfusion modeller **120**.

[0033] The additional information may also include patient physiological parameters **216**. Such parameters may include, and are not limited to, blood pressure, heart rate, and the like. In one instance, these parameters are measured and provided by an operator. In another instance, these parameters may additionally or alternatively be provided by an external information source such as a Radiology Information Source (RIS), a Picture Archiving and Communication System (PACS), and/or other medical information storage, retrieval and distribution system. In another instance, these parameters may additionally or alternatively be derived from image data such as CTA image data. The additional information may additionally include patient medical history.

[0034] The illustrated perfusion modeller **120** uses the above discussed input to generate the patient specific perfusion model. As such, the patient specific cerebral perfusion model is based on the CTP image data, the general perfusion model, and the additional information. The patient specific cerebral perfusion model may include information indicative of CBF, CBV, MTT, TTP, and/or one more other parameters. As discussed above, such information along with various image data is presented to the operator via the user interface **122**, and an operator can add, modify, and/or delete various inputs to the perfusion modeller **120** via the user interface **122**. Upon any changes by the operator, the perfusion modeller **120** generates an updated or new patient specific perfusion model based on the CTP image data and the general perfusion model and the additional information with any changes made thereto.

Although the perfusion image data in the above examples is acquired by the CT scanner **100**, it is to be appreciated that perfusion image data can additionally or alternatively be acquired by another imaging modality such as MR, US, SPECT, PET, etc.

[0035] Operation is now described in connection with FIG. **3**.

[0036] At **302**, a general cerebral perfusion model is obtained. This model may be based on systematic, cardiac, vascular structure, and/or other parameters.

[0037] At **304**, image data indicative of pathologies of the vascular system and/or of cerebral mal-perfusion is obtained. Such data may be acquired by the CT scanner and/or another type of scanner.

[0038] At **306**, vascular pathologies are identified and quantified. Briefly turning to FIG. **4**, an example of this is illustrated. At **402** a set of CTA (and/or MRA and/or DSA) images of the heart and brain are obtained. At **404**, the set of images is segmented to generate a vessel tree structure. At **406**, a pathology in the vessel tree structure is detected using a generic model of the vascular structure. At **408**, the pathology is quantified.

[0039] Returning to FIG. **3**, at **308** patient specific physiological parameters are obtained. Such parameters include, but are not limited to, the systemic parameters, the cardiac parameters, the vascular parameters, and/or the other parameters.

[0040] At **310**, the perfusion modeller **120** determines a patient specific cerebral perfusion model based on a general perfusion model, the image data, the quantification of the identified pathologies, the patient specific parameters, and a patient history. Turning to FIG. **4**, this is shown at **410**.

[0041] Returning to FIG. **3**, at **312**, the patient specific perfusion model is presented to the operator via a user interface or the like.

[0042] At **314**, the operator may modify or adjust the general perfusion model, the image data, the identified pathologies, the patient specific parameters, and/or the patient history. If the operator makes any modifications or adjustments, then at least act **310** is repeated, and a new patient specific cerebral perfusion model is presented at **312**.

[0043] The above may be implemented by way of computer readable instructions, which when executed by a computer processor(s), cause the processor(s) to carry out the described acts. In such a case, the instructions are stored in a computer readable storage medium associated with or otherwise accessible to the relevant computer. The acts need not be performed concurrently with data acquisition.

[0044] The invention has been described herein with reference to the various embodiments. Modifications and alterations may occur to others upon reading the description herein. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

1. A perfusion analysis system, comprising:

a perfusion modeller that generates a patient specific perfusion model based on medical imaging perfusion data for the patient, a general perfusion model, and a quantification of one or more identified pathologies of the patient that affect perfusion in the patient; and

a user interface that accepts an input indicative of a modification to the one or more identified pathologies, wherein the perfusion modeller updates the patient specific perfusion model based on the medical imaging perfusion data for the patient, the general perfusion model, and the quantification of the one or more identified pathologies of the patient, including the modification thereto.

2. The system of claim **1**, wherein the modification includes an addition of a pathology.

3. The system of claim **1**, wherein the patient specific perfusion model includes a cerebral perfusion model.

4. The system of claim **1**, wherein the general perfusion model is based at least on a systemic parameter, a cardiac parameter, and a vascular structure parameter.

5. The system of claim **4**, wherein the vascular structure parameter includes at least one parameter indicative of at least one of cerebral mal-perfusion or delayed mean transit time.

6. The system of claim **4**, further including an image analysis tool that determines the vascular structure parameter, wherein the image analysis tool includes:

a segmentation component that segments image data to obtain image data indicative of corresponding vascular structure; and

a parameter determiner that determines the vascular structure parameter based on the segmented image data.

7. The system of claim **6**, further including an identification tool that identifies and quantifies a pathology based on the segmented image data and the vascular structure parameter.

8. The system of claim **7**, wherein the identification tool includes a quantifier that compares the segmented image data with a vascular system model to identify the pathology.

9. The system of claim **1**, wherein the perfusion modeller generates the patient specific perfusion model based on one or more patient physiological parameters including at least one of blood pressure or heart rate.

10. The system of claim **1**, wherein the perfusion modeller generates the patient specific perfusion model based on a patient medical history of the patient

11. The system of claim **1**, wherein the patient specific perfusion model includes at least one of a cerebral blood flow map, a cerebral blood volume map, a mean transit time map, or a time to peak map.

12. The system of claim **1**, wherein the medical imaging perfusion data is acquired by a computed tomography scanner.

13. A brain perfusion analysis method, comprising:

identifying a first pathology of the vascular system;

quantifying the first pathology; and

generating a first patient specific brain perfusion model based on the quantification of the first pathology, a general brain perfusion model, and brain perfusion imaging data.

14. The brain perfusion analysis method of claim **13**, further including:

identifying a second pathology of the vascular system;

quantifying the second pathology; and

generating a second patient specific brain perfusion model based on the quantification of the first pathology, the quantification of the second pathology, the general brain perfusion model, and the perfusion imaging data.

15. The brain perfusion analysis method of claim **14**, further including:

discarding the first pathology; and

generating a third patient specific brain perfusion model based on the quantification of the second pathology, the general brain perfusion model, and the perfusion imaging data.

16. The brain perfusion analysis method of claim **13**, wherein the identification of the first pathology includes comparing image data indicative of at least a sub-portion of the vascular system with a vascular system model including known pathologies.

17. The brain perfusion analysis method of claim **13**, further including:

segmenting computed tomography angiography image data to obtain a vascular tree structure; and

determining a vascular parameter of the vascular tree structure, wherein the first pathology is identified in the vascular tree structure based on the vascular parameter.

18. A computer readable storage medium containing instructions which, when executed by a computer, cause the computer to perform the steps of:

identifying a pathology of the vascular system;

quantifying the pathology; and

generating a patient specific brain perfusion model based on a quantification of the pathology, a general brain perfusion model, and a perfusion imaging data.

19. The computer readable storage medium of claim **18**, wherein the instructions, when executed by the computer, further cause the computer to perform the step of:

presenting the patient specific brain perfusion model in a human readable format in a user interface, wherein the user interface allows a user to modify the identified pathology.

20. The computer readable storage medium of claim **18**, wherein the instructions, when executed by the computer, further cause the computer to perform the step of:

presenting the patient specific brain perfusion model in a human readable format in a user interface, wherein the user interface allows a user to add a second pathology.

21. The computer readable storage medium of claim **20**, wherein the modification includes adding a second pathology.

generating a second patient specific brain perfusion model based on the quantification of the pathology, a quantification of the second pathology, the general brain perfusion model, and the perfusion imaging data

22. The computer readable storage medium of claim **18**, wherein the instructions, when executed by the computer, further cause the computer to perform the step of:

generating the patient specific brain perfusion model based on patient vital signs and patient medical history.

* * * * *